Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

18 ARO

REPORT DOCUMENTATION PAGE

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19

1. REPORT NUMBER: 13168.10-MS

2. GOVT ACCESSION NO.: 12

3. RECIPIENT'S CATALOG NUMBER: 9

4. TITLE (and Subtitle): 6 Crack Propagation in Structural Ceramics Subjected to Thermal Stress.

5. TYPE OF REPORT & PERIOD COVERED: Final Report, 15 Nov 75 - 31 Aug 77

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): 10 E. P. Chen, D. P. H. Hasselman

8. CONTRACT OR GRANT NUMBER(s): 15 DAAG29-76-G-0091

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Lehigh University
Bethlehem, Pennsylvania 18015

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS:
U. S. Army Research Office
Post Office Box 12211
Research Triangle Park, NC 27709

12. REPORT DATE: 11 Aug 77

13. NUMBER OF PAGES: 4

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 5p.

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Crack propagation	Aluminum oxides	Glass
Ceramic materials	Silica glass	Fragmentation
Thermal stresses	Silicon nitrides	Brittleness
Fatigue(materials)	Silicon carbides	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This program was devoted to the thermal fatigue behavior and failure prediction of structural ceramics under thermal stress. The materials investigated include soda-lime-silica glass, silicon nitride, silicon carbide and alumina. Another phase of the program dealt with the self-fatigue in surface compression strengthened glass plates. That the strength of glass plates can be improved by introducing residual stresses into the material is well known. However, brittle glass strengthened in this manner appears to be susceptible to spontaneous fragmentation even during the complete absence of applied loads. The problem was analyzed from the fracture mechanics point of view.

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ARO-13168.10-MS

FINAL REPORT

Crack Propagation in Structural Ceramics Subjected to Thermal Stress

by

E. P. Chen, D. P. H. Hasselman

Report Period: November 15, 1975 - August 31, 1977

Grant No.: DAAG29-76-G-0091

August 31, 1977

Institute of Fracture and Solid Mechanics
Lehigh University
Bethlehem, PA 18015

FINAL REPORT

1. ARO-D Proposal Number: 13168-MS
2. Period Covered by Report: November 15, 1975 - August 31, 1977
3. Title of Proposal: Crack Propagation in Structural Ceramics Subjected to Thermal Stress
4. Contract or Grant Number: DAAG29-76-G-0091
5. Name of Institution: Lehigh University
6. Authors of Report: E. P. Chen, D. P. H. Hasselman
7. List of Manuscripts Submitted or Published Under ARO-D Sponsorship During This Period, Including Journal References: See attached list.
8. Scientific Personnel Supported by This Project and Degrees Awarded During this Reporting Period: K. Arin, M. Bakioglu, E. P. Chen, P. A. Urick

List of Publications

1. "Failure Prediction of the Thermal Fatigue of Silicon Nitride", J. Am. Ceram. Soc. 58 (11-12) 513, 1975.

2. "Failure Prediction of the Thermal Fatigue Resistance of a Glass", J. Mat. Sci. 11 (3), 458, 1976.

3. "Crack Growth and Thermal Fatigue of Brittle Ceramic Materials", Inter Ceram. 25 (1) 59, 1976.

4. "Thermal Fatigue and Its Failure Prediction for Brittle Ceramics", ASTM STP 612, 55, 1976.

5. "Comparison of the High-Temperature Thermal Fatigue Resistance of Hot-Pressed Silicon Nitride and Silicon Carbide:, J. Am. Ceram. Soc. 59 (11-12) 525, 1976.

6. "Fracture Mechanical Analysis of Self-Fatigue in Surface Compression-Strengthened Glass Plates:, J. Mat. Sci. 11, 1826, 1976.

7. "The Role of Activation Energy of Slow Crack Growth in the High-Temperature Thermal Fatigue of Silicon Nitride", J. Am. Ceram. Soc. 60 (1-2), 76, 1977.

8. "Impact Response of a Layered Composite Containing a Crack", J. Acoust. Soc. Am. 61 (3) 727, 1977.

9. "Sudden Twisting of a Penny-Shaped Crack in a Finite Elastic Cylinder", Fracture 1977, Vol. 3, Ed. by D. M. R. Taplin, 71-78, University of Waterloo Press, Waterloo, Canada, 1977.

10. "Impact Response of a Finite Crack in a Finite Strip Under Anti-Plane Shear", Eng. Fracture Mech. (in Press).

11. "Transient Elastodynamic Stress Intensity Factor in a Composite Cylinder Under Torsion", Proc. Int. Conf. on Fracture Mech. and Tech. (in Press).

12. "Role of Physical Properties in the Resistance of Brittle Ceramics to Failure by Thermal Buckling", J. Am. Ceram. Soc. (Submitted for publication).

13. "Prediction of the Thermal Fatigue Resistance of Indented Glass Rods", J. Am. Ceram. Soc. (in Press).

14. "Prediction of the Self-Fatigue of Surface Compression Strengthened Glass Plates", Proc. Int. Symp. on Fracture Mech. of Ceram., (in Press).

15. "Effect of Surface Indentations on the Relation Between Strength and Thermal Stress Resistance of Soda-Lime Glass", (Submitted for Publication).

BRIEF OUTLINE OF RESEARCH FINDINGS

This program was devoted to the study of the thermal fatigue behavior and failure prediction of structural ceramics under thermal stress. The materials investigated include soda-lime-silica glass, silicon nitride, silicon carbide and alumina. In general, the agreement between the semi-analytical prediction, making use of the slow crack growth data and the experimental data were good. The uncertainty comes largely from estimating the proper initial flaw depth by using the Weibull theory. To this end, a study to eliminate the statistical effect was conducted on soda-lime-silica glass. Artificial surface flaws were introduced to the specimen by diamond indentation before it was subjected to repeated water quenching. Good agreement between calculated and observed fatigue behavior was obtained without the need of statistical theory of brittle fracture.

Another phase of the program dealt with the self-fatigue in surface compression strengthened glass plates. The strength of glass plates can be improved by introducing residual stresses into the material is well known. However, brittle glass strengthened in this manner appear to be susceptible to spontaneous fragmentation even during the complete absence of applied loads. The problem was analyzed from the fracture mechanics point of view. The results indicated that slow crack growth from static fatigue is indeed a possible mode of failure in surface compression strengthened glasses. Ways of reducing the static fatigue damage in glass plates were suggested.

Analytical studies on the elastodynamic behavior of brittle solids subjected to rapidly applied loads were carried out in this program. Various crack geometry and material configuration were considered. It was found that the interaction between dynamic loads and reflected waves from the finite boundaries and/or material interfaces can increase the load transfer to the crack tip and consequently, the allowable load in impact is considerably less than its static counterpart. This type of analysis is essential for the design of components made of brittle materials.